

OVERVIEW OF ADVANCED CIM FOR SHIPBUILDING PROJECT

– VISION AND REFERENCE ARCHITECTURE

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Abstract

The Advanced Computer Integrated Manufacturing (ACIM) for shipbuilding project sponsored by Ship and Ocean Foundation (SOF) and participated by seven major shipbuilders in Japan, was launched in 1997 with a planned duration of three years. The goal of ACIM project is to enable highly effective, efficient and flexible collaborative engineering for shipbuilding based on knowledge sharing among multiple disciplines by developing practical product/process model and promoting network based software integration environments. To achieve the goal, we have developed a CORBA-based reference architecture that enables integration and management of distributed objects and systems including newly developed applications and existing legacy systems. The aspect of the construction of the future virtual enterprises has also been considered in the development of the reference architecture. In this paper, we provide an overview of the ACIM project and present the ACIM reference architecture.

Introduction

Since 1989, a series of research and development projects on the CIM for shipbuilding has been carried out by Ship and Ocean Foundation together with seven major shipyards in Japan, aiming at drastic increase of productivity in shipbuilding industries. Figure 1 shows the history of CIM projects. The concept of CIM for shipbuilding, which is rather different from mass productive industries such as automobile industries, was established in the first project. The importance of ship product model was recognized and has since been emphasized throughout the CIM related projects. The specification of product model was established in the second project. Object oriented technologies have been widely applied for the system analyses as well as system implementation since the first project. In the GPME project, the preceding project of ACIM, the general product model environment was developed for the efficient development of product model. The results generated from these R&D activities have been transferred to the Japanese major shipyards. All seven shipyards have established their own CIM systems based on the results of the CIM research projects.

The ACIM project was launched in the spring of 1997 with a planned duration of three years. The vision of ACIM project is to enable highly effective, efficient and flexible collaborative engineering environment for shipbuilding based on knowledge sharing among engineers from multiple disciplines. Developing product and process models is one of the major R&D tasks in this project since they are the basis for knowledge sharing. Another important task is to establish a distributed object and system environment based on CORBA (Common Object Request Broker Architecture). Other emerging information technologies such as agent technology is also introduced for better engineering work support and information exchange through network.

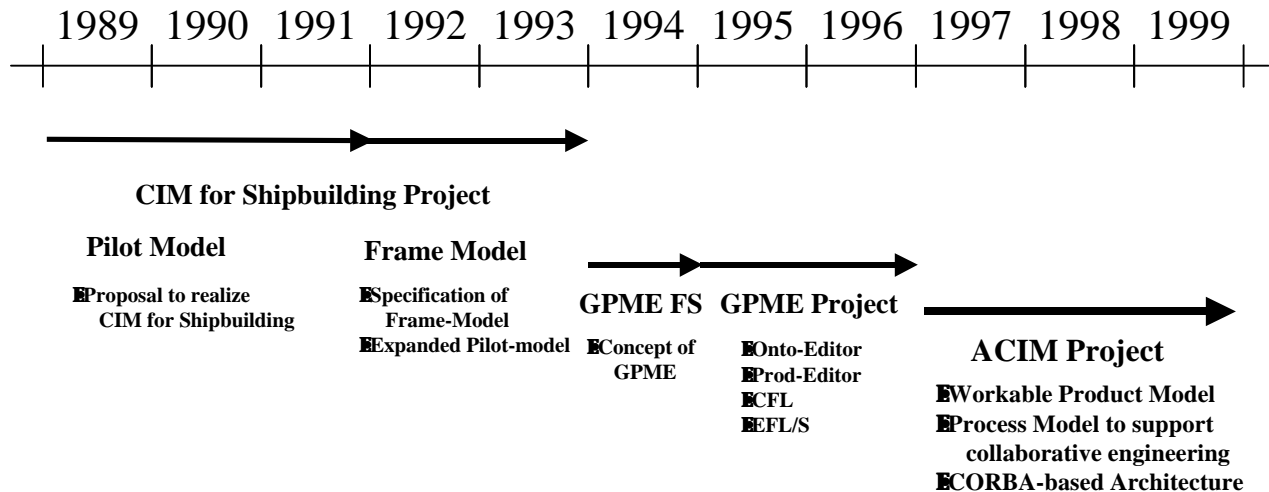


Figure 1. History of SOF CIM Project

Goal and Objectives

As stated above, the overall goal of ACIM project is to develop a system framework to support the collaboration among engineers in design and production in shipbuilding.

The specific goals of the project include:

1. To develop a CORBA-based ACIM reference architecture that enables integration and management of distributed objects/models in the network and supports concurrent engineering of shipbuilding
2. To construct a practical product model through the extension of the Frame Library developed in the preceding GPME project
3. To define a process-driven collaborative engineering work paradigm
4. To develop a process model for engineering support that can adapt dynamically changing actual engineering process
5. To develop intelligent agent based collaboration support mechanism
6. To test the system infrastructure using real shipbuilding case scenarios

The deliverables generated by this project, such as product model and applications, are not prototype systems but are practical application systems and will be used in actual ship design and production. “Practical”,—i.e., real—is one of the key words in this project. Therefore, the issues related to deployment of the deliverables to the shipyard are also included in the project scope.

Needs for Knowledge Sharing

Shipbuilding is a typical example of concurrent engineering where the information is exchanged intensively between engineers at different stages and continuously updated by multiple

disciplinary engineers. The main goal of ACIM project is to develop a system infrastructure to support this collaboration by using advanced information technologies and to achieve information and knowledge sharing for high efficiency.

To share the knowledge and information about shipbuilding among multiple engineers and furthermore between engineers and computers, one needs both product and process models. Sharing engineering information through a common product model has been proven to be an effective way for engineering team members to identify inconsistencies and generate timely information flows. By accessing a logically centralized product model database, an engineer can retrieve the latest engineering information generated by other engineers and pass his or her task results to others through the database.

While shared product model can be used to facilitate information flows among engineers, it contains only the results generated by engineers. The information of the process through which the results were generated is not part of a product model. Another important aspect of engineering knowledge is about engineering processes. Engineering tasks are not carried out in a random way. Rather, they are well planned and managed based on the planned processes. An engineering process is composed of a set of interrelated activities that collectively realize certain engineering objectives.

Furthermore, there are many applications prepared for the engineering support for design and production. These applications are developed based on shipbuilding specific domain knowledge. It can be said that the specific knowledge of design and production of shipbuilding is expressed by product model, process model and applications that are distributed in the network.

The information technology about distributive objects is emerging nowadays. This technology secures interoperability and adaptability between software systems. Interoperability means how easily a software can be integrated into various other systems and adaptability denotes how one system can be upgraded following the latest technology. This information technology of distributed objects enables us to construct a network-based collaborative environment for ACIM.

Common Object request Broker Architecture

OMG is a software standardization organization that promotes Object-Oriented technologies for integrating heterogeneous and distributed computer systems. OMG's system building concept is described as OMA (Object Management Architecture), the architecture aiming at global network oriented software linking environment. The standard defined by OMG is called CORBA (Common Object request Broker Architecture). It is natural way to adopt CORBA standard to realize above mentioned ACIM collaboration support environment. The specification of CORBA defines how to make interface which is compliant to OMA's architecture. CORBA enables OMA concept in the following four mechanisms.

- OMG IDL (Interface Definition Language) is used to define software interface grammatically.
- ORB (Object Request Broker) is incorporated to simplify the transaction in heterogeneous and distributed computer system environment.
- OMG IDL written interface facilities called Basic Object Service and Common Facility are defined.
- CORBA Object-Oriented approach enables interoperability and adaptability.

CORBA basic object services are implemented by software vendors as CORBA product. Software components with interoperability and adaptability can be developed by use of CORBA product. CORBA can mask the discrepancy of computer systems (i.e. hardware platforms, software language, data access mechanisms, compiler versions, component module interfaces, network protocol

etc.) and there are several wrapping methods to accomplish it.

ACIM Reference Architecture

As described above, CORBA, the distributed object technology, is an important information technology to build the system infrastructure for ACIM since we want to achieve knowledge and information sharing through the integration of applications and data without worrying about hardware or software platforms.

This CORBA-based system environment enables to continuous extension of ACIM through the addition of the new software components and the integration with existing systems. In order to construct the ACIM based on distributed objects environment, it is required to define reference architecture as the system development framework. The architecture is basically designed by referring to the OMA proposed by OMG. The specific requirements that comes from the concept of the advanced CIM for shipbuilding system has been taken into consideration for construction of reference architecture.

1. Product model that represents knowledge and information about ship product and process model that represents knowledge and information about ship engineering process are two core models for knowledge description.
2. The effective services/facilities to support collaboration of engineers, which can be commonly used in ACIM environment, have to be provided.
3. It should be described in the architecture that the ACIM can be enhanced according to the preparation for the domain specific services concerning ship structural design and pipe design.
4. From the practical view point, special consideration must be paid to the integration with legacy systems used in the shipyards.

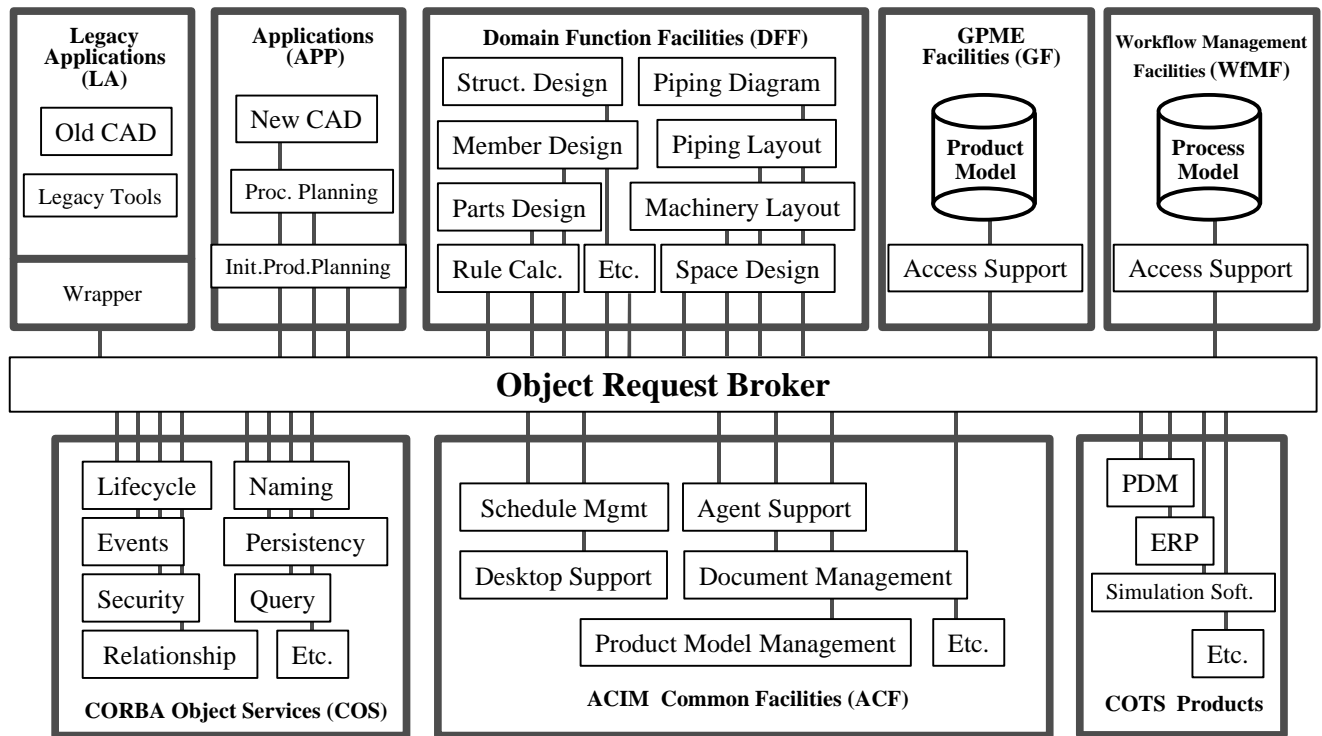


Figure 2. ACIM Reference Architecture

The ACIM reference architecture is shown in Figure 2. In this architecture, eight (8) interface categories are defined according to the functionality of software components which provide necessary facilities and services to support concurrent engineering of engineers. ORB plays an important role to associate these software components included in these categories.

In the following, we describe the functionality of each category and implementation of these categories.

CORBA Object Services : COS

This category corresponds to the Basic Object Services, one of architectural components of OMA described in previous section. These services are the basic services to construct distributed object system. The specifications on functionality of each service are defined by OMG and software vendors implement its functionality based on these specifications. There are several commercial CORBA products available nowadays. The specification of object services has been already defined by OMG and published. At the moment, there are sixteen (16) services defined as specification, such as “Naming service” for linking object’s name and real object, “Event service” for asynchronized communication. In the ACIM project, we adopted “Orbix” from IONA Technology as the CORBA product.

GPME Facilities : GF

GPME facilities provides the access facilities to the product model which is implemented in the previous GPME project and extended to the practical level in the ACIM project. The versatile access to the product model is available through open natured IDL interfaces. The instantiation and

retrieval of instances from product model are performed through this services. The important point is that we have adopted the late binding method for implementation, so all the class methods which have been already implemented in Frame Library and also new methods which may be added in future are available as a CORBA objects in ACIM environment through this access facilities. The late binding enables to specify dynamically the functions or method when application is executed. This means it is not necessary to define the IDL interfaces and implement it one by one. Even in the case that extension or modification of certain method is occurred, only the recompilation of source program has to be done.

Workflow Management Facilities : WfMF

As was described above, we regard the process model as one of core model to express knowledge about shipbuilding process and to realize collaborative engineering environment. In ACIM project, we propose a process-driven work paradigm for collaboration support. The paradigm will be briefly described in the succeeding section and the details are presented in another paper submitted to ICCAS.

This category provides the necessary functions to realize process-driven work paradigm. Two important servers have been identified as system components of work support system. The components are Process Server and Enterprise Resource Server. The functions of Process Servers include capturing process models and managing process execution based on the process models. For process execution management, Process Server generates activation signals, control the real process by reasoning based on the given rules. On the other hand, Enterprise Resource Server centralizes resource information logically. To manage engineering processes, resource information is very important. It has also process templates and journal information about the results of engineer's operation or communication. The services corresponding these functions are provided by WfMF facilities.

Domain Function Facilities : DFF

DFF is the category which includes shipbuilding specific functions necessary to develop applications. The DFF facilities provide the services based on the shipbuilding ontology. The applications are developed mainly on the basis of these DFF facilities. The functions are dependent on the kinds and functions of applications to be developed. Theses DFF facilities are sometimes used for several applications, and furthermore one DFF function may be used by other DFF facilities as the primitive services. The DFF facilities provide functions for application development by combination of GF services such as assessor and methods which GF provides.

As mentioned before, the services provided by GF are implemented by late binding method. This means all the methods provided by product model are available as the CORBA facilities. The methods included in the GF category contains rather higher level functions such as calculating the weld length and weight calculation about intermediate assembly products. Due to the late binding method, these functions are provided by the GF facilities. The examples of DFF are shown in the another paper submitted to ICCAS.

Applications : APP

In this reference architecture, applications are defined as the new applications used in shipbuilding design and production which has been developed on the basis of the ACIM reference architecture and adapted to the CORBA-based ACIM open environment, i.e. distributed object environment. In ACIM environment, applications are developed efficiently combining the services and facilities provided by software components included in other categories of ACIM reference

architecture. In this project, two (2) applications for production planning are developed in a practical level for the purpose of the verification of ACIM product model.

Legacy Applications : LA

This category contains all the applications, such as CAD systems and other domain specific applications to support design and production work, currently used in the shipyard. These applications does not have the adaptability to the CORBA environment. So it is impossible to communicate with other applications through CORBA. However, from the practical view point, it is very important to exchange information between these legacy applications and software object developed under the ACIM open environment. So these applications have to be adapted to the ACIM environment. CORBA enables to make these legacy applications adapt to the ACIM open environment. The software added to the legacy applications in order to make it adaptable to CORBA environment is called wrapper. Through the wrapper, legacy applications can communicate with new applications or COTS products adaptable to CORBA environment. On the contrary, it is also possible to make the functional components included in the legacy applications as a software component that can be used by other applications. CORBA provided the great advantage that makes the legacy application adaptable to distributed object environment. This means that the a part of legacy application can survive as a software component for a long time.

ACIM Common Facilities : ACF

Software components in this category provides the general services commonly used in other software components. These components are independent from the domain specific ontology, so these are widely used from many applications. Commercial software components not compliant with CORBA environment can be adapted to the ACIM environment by adding a wrapper and added as the new service. In this way, the new software components can be added easily to ACIM services.

On the other hand, the native services are developed and prepared as the ACF services in this project. These are agent facilities and product model management facilities. As theses facilities are independent from shipbuilding domain ontology, services are categorized as ACF.

Example of services provided are schedule management, agent supported functions that may be used in the process-driven ACIM collaborative environment, product model management facilities that is indispensable for operational phase in a shipyard. Furthermore, ACIM desktop, work environment for ACIM users, is developed in this project. Services necessary to develop ACIM desktop are provided as ACF.

COTS (Commercial-Off-The-Shelf) Products

This category includes the COTS products which provide CORBA compliant services. The concept of integration of distributed systems based on CORBA is widely accepted. Software venders such as PDM(Product Data Management) and ERP(Enterprise Resource Management) are now moving to adapt their software products to CORBA. Furthermore, the consortium of PDM venders are trying to define the standardized IDL interfaces aiming at the information exchange between different PDM products. Also it is expected that the software venders which are specialized in development of software component will emerge in near future according to the progress of the distributed object technology progress. By using best-breed COTS and/or combining effectively commercial software components, the application development environment will be much improved.

On the other hand, in the world of Microsoft Windows, distributed object linking mechanism DCOM(Distributed Common Object Model) has been formalized. Many software component products are available nowadays. For example, Microsoft Transaction Server can be easily customized

by selecting and combining software components implemented as the DCOM objects. As will be explained later, it has already been confirmed through the prototype test that the information exchange between CORBA and DCOM can be realized with ease by use of CORBA/DCOM bridge provided by CORBA commercial products. This means that the libraries compliant for DCOM can be used from CORBA world. Therefore it is expected that increase of commercial software components compliant with DCOM enable efficient application development even in CORBA environment.

As was described above, the Advanced CIM system which enables highly efficient collaborative engineering can be realized on the basis of CORBA-based ACIM reference architecture. The flexible exchange of information and knowledge through network can be realized by CORBA. Services physically distributed in the network can be used regardless of the hardware/software platform. The information exchange between applications become possible over the enterprise.

Verification of CORBA Based System Through Prototyping

In order to clarify the technical issues prior to the actual development we have carried out the verification of CORBA-based system by prototyping. The scenario of prototype system is as follows;

- Firstly, a test application access to the product model to get all parts from specified assembly block
- Secondly, the calculation of weight and welding length of specified assembly block is carried out by using services included
- Display the results to a screen in graphical way by Java applet

The prototype scenario is very simple one, and it includes services of several categories such as CORBA Object Services(COS), Domain Functional Facilities(DFF), GPME Facilities(GF) and Applications(APP), and it is enough to verify the possibility about the CORBA based systems. Figure 3 shows the prototype test environment.

We have confirmed through this prototype system that there is no specific technical issue for developing the CORBA-based system. The performance overhead is not so big in case that the granularity of service is not so small. We have also carried out another prototype test concerning about CORBA/DCOM linkage. The test scenario is to get information from product model on the EWS and to transfer it to the spread sheet on the PC. The functions provided by commercial CORBA products as a CORBA/DCOM bridge was used in the test. We have confirmed that the data exchange between CORBA object and DCOM object can be realized without any problem. This means that the services implemented as DCOM object can be utilized in ACIM environment.

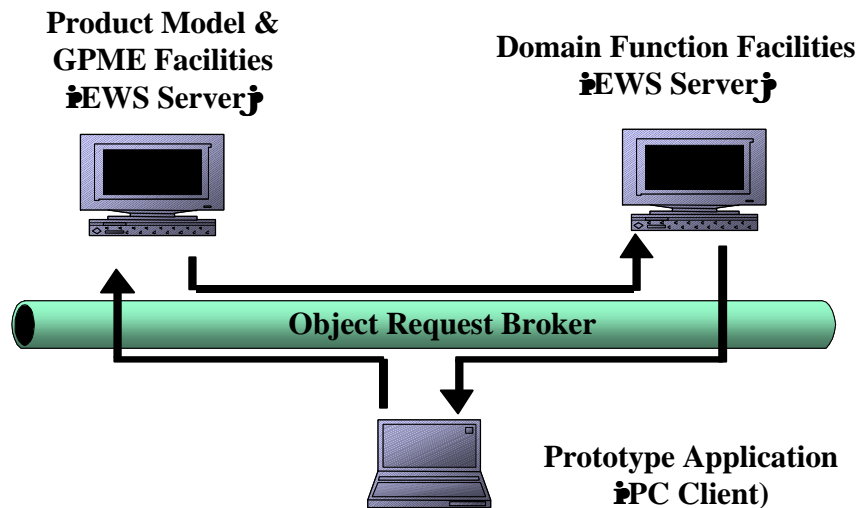


Figure 3. Prototype Test Environment

Development of Practical Product Model for Shipbuilding

Now, we will explain another important issues in the ACIM project. In the ACIM project, it is recognized that product model which expresses knowledge and information concerning ship as a product plays key role for the knowledge sharing. Thus, the product model should have enough ability to express information and knowledge on actual ships and should be practical. One of the important R&D tasks in the project is to establish the practical product model for shipbuilding, which express ontology of shipbuilding. When developing the workable product model, maximum usage is made of GPME (General Product Model environment) which has been developed in the preceding CIM project. In the GPME project, CFL(Common Frame Library), the information model to express common ontology for assembly industries has been extended to EFL/S (Extended Frame Library for Shipbuilding) which includes the ontology for shipbuilding. However, it was a relatively small extension only for verifying the usefulness of GPME as a product model development software tools. In the ACIM project, extension of EFL/S is being carried out to much more practical level. The product model is realized by combined use of CFL and EFL/S and becomes the base for the engineer's collaboration. EFL/S is now being extended in two directions as shown in Figure 4. One is to enhance the product model so as to be rich in the modeling flexibility; this lead to the easy design alteration and simulation. Another is to extend the expression capability so as to express most of the hull structures including details and almost all outfitting of actual ships. The details of the practical product model construction is referred to paper submitted by other authors.

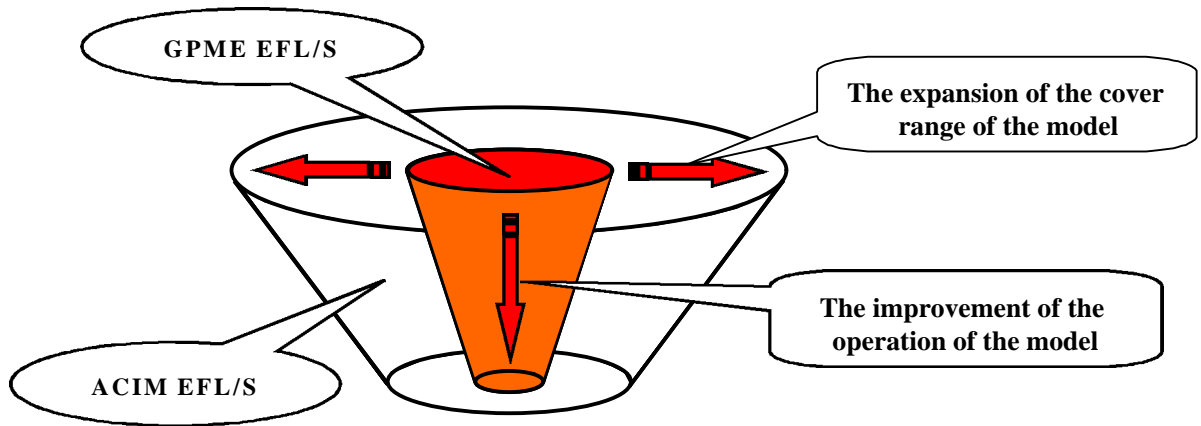


Figure 4. Extension of EFL/S in Two Directions

Development of Process Model To support Collaborative Engineering

While knowledge about engineering products captured by product models is important for engineering support and needs to be shared among distributed engineers and systems, another important aspect of engineering knowledge is about engineering processes. In ACIM project, the process model that represents the knowledge and information about engineering process is one of the core models for collaboration through knowledge sharing. Engineering tasks are not carried out in a random way. Rather, they are well planned and managed based on the planned processes. An engineering process is composed of a set of interrelated activities that collectively realize certain engineering objectives. A process model is a representation of a engineering process in a form which supports automated manipulation or enactment by a process management system. Process model includes the control information that defines how engineering activities should be carried out and how they relate to each other.

In ACIM project, we propose a framework based on a process-driven and agent-supported approach to collaborative engineering support called Active Process. The process model developed in Active Process has a capability to describe 'how engineering tasks should be done' in order of precedence. It is powerful but still not sufficient because engineering task procedures will be often changed according to situation. To meet this problem, agent-supported approach is introduced to Active Process. Each participant in the system has its own agent who is interested in negotiation with others to acquire information.

Figure 5 illustrates how process information represented as process models can be used to support engineering work and collaboration. The details of the proposed framework is presented in another paper submitted by other authors.

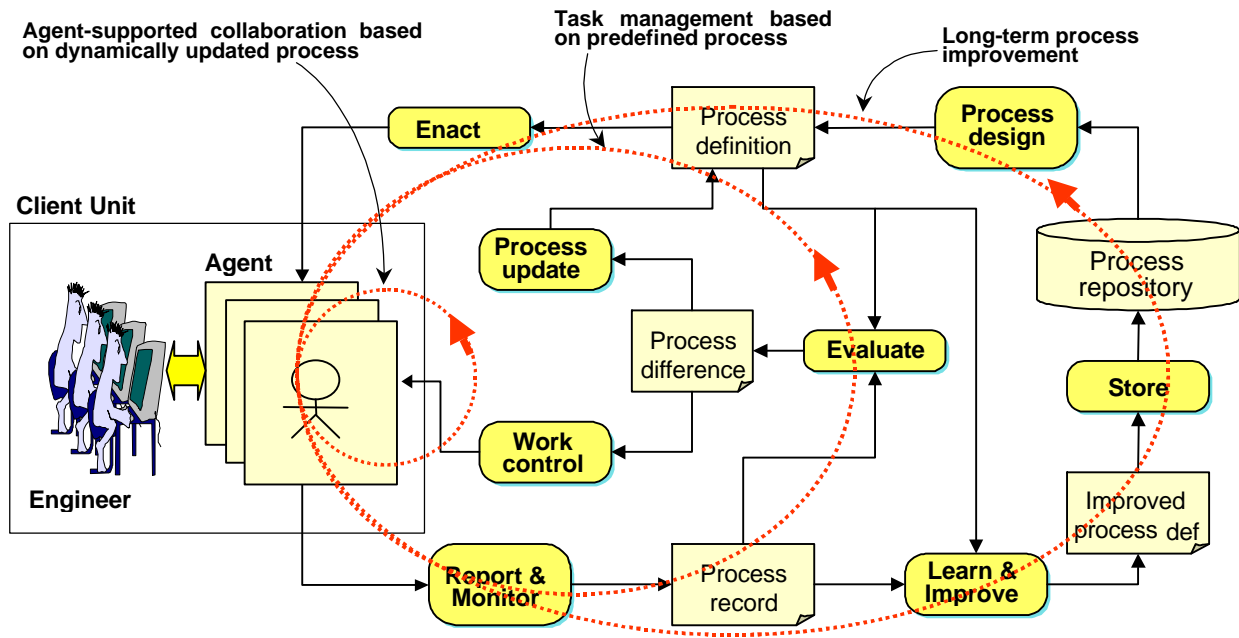


Figure 5. Process Model and its Application for Engineering Support

Verification of Product Model and Collaborative Engineering Environment

Verification of Enhanced and Extended Product Model

As was stated in the previous section, product model (mainly the EFL/S) is now being extended in two directions, i.e. one for enhancement on the functions such as modeling flexibility and the other for the extension of expression capability. We take different verification approach for these two extensions.

As for the verification of enhancement of functions such as modeling flexibility, we take an approach to verify it through the development of applications and their execution for the enhanced product model. The application is being developed by using the class methods provided by enhanced product model. The application must be a practical one, not a prototype, in order to evaluate functionality of product model more correctly. Two applications are now being developed for this purpose. One is an application to support initial production design so-called block breakdown (ACIM IPD : Initial Production Design), while another is an application to support process planning (ACIM CAPP : Computer Aided Process Planning). These applications are developed on the basis of the ACIM reference architecture. The services provided by GF, DFF and COS of ACIM reference architecture are used to develop these applications. Details of the applications are described in the paper submitted by other authors.

As for the verification of the extension of model expression capability, we take an approach to verify it through the exchange of model information for actual ships generated by CAD system being used in the shipyard. As the model data of shipbuilding CAD system now in practical use can express most of the hull structures including details and almost all outfitting of actual ships. Therefore, if these information can be transferred to the ACIM product model and successfully stored, it is confirmed that the extended product model has enough coverage to express actual ship structures and outfitting

items.

In order to exchange data between product model and CAD system in shipyards, we are now developing the dual-direction data transmission application. This application is also developed on the basis of the ACIM reference architecture. The data exchange test will be carried out using this software. As the software is so developed as to be able to exchange in dual direction, the results obtained from ACIM IPD and CAPP described above is transferred to the existing CAD system in shipyards and continuously used in the practical design. This means that this data exchange software can be used in a actual ship design process.

Verification of Collaborative Engineering Environment

The goal of ACIM project is to establish the system infrastructure using advancing information technologies which enable efficient and flexible collaborative engineering environment for shipbuilding on the basis of the knowledge sharing. We plan to verify it based on a set of test scenarios. In the test scenarios, all the deliverables obtained from the project such as practical product model, applications of ACIM IPD and CAPP and process model are taken into consideration. In the project, we are planning to propose the ACIM desktop which is newly developed user's work environment with enhanced graphical interface. The process-driven and agent-supported mechanism for collaborative engineering support mentioned in the previously section will work on this ACIM desktop. The verification of collaborative engineering environment will be carried out through this desktop according to the test scenario.

Conclusions

In this paper we presented an overview of our on-going ACIM project, focusing on the ACIM reference architecture. The vision of ACIM project is to enable highly effective, efficient and flexible collaborative engineering environment for shipbuilding based on knowledge sharing between multiple disciplines by developing practical product/process model and promoting network based software integration environments.

In order to achieve our goals, we have developed an OMG CORBA-based reference architecture that enables integration and management of the distributed objects, models, and systems including newly developed applications and existing legacy systems currently used in shipyards.

Our proposed ACIM reference architecture represents a framework of the advanced CIM systems. This architecture is open to the outer world and adaptable for the emerging information technologies. The product model and process model are defined as the core components of knowledge sharing ACIM environment. The practical product model is developed in this project. This product model is used in the shipyard after this project is completed.

We propose a framework based on a process-driven and agent-supported approach to collaborative engineering support called Active Process.

The verification of the enhanced product model and collaborative environment is carried out through the newly developed applications.

The progress of information technology is being accelerated nowadays. The ACIM reference architecture based on the distributed object oriented paradigm is very flexible enough to incorporated the new technologies. We believe that the ACIM reference architecture provides a platform for continuous improvement of CIM for shipbuilding.

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